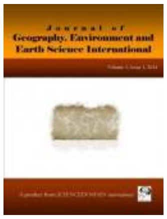

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Influence of Parent Materials and Land Use on Exchangeable Cations in a Tropical Environment

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Authors' contributions

This work was carried out in collaboration between both authors. Author POO designed the study, wrote the protocol and the first draft of the manuscript. Both authors managed the literature searches, collected the soil samples and discussed the results. Author PAOO read and approved the final manuscript.

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ABSTRACT

Present research was undertaken to examine the influence of parent materials and land use on exchangeable cations in Edo state, Nigeria. This investigation was carried out with the following objectives (i) to examine the status of exchangeable cations in the soils (ii) to determine the difference in the exchangeable cations of soils amongst the different land use types in Okodobo Village. Eighteen soil samples (0-15 cm and 15-30 cm depths) were collected from three study sites viz., Secondary forest (control site) and Plantain and Oil palm (treatment sites) plantations. Exchangeable cations were analyzed using standardized methods and analyzed employing soil quality index and student t -test. The analytical results confirmed that the status of Ca^{++}, Mg^{++} and Na^{+} were deficient, K^{+} was however not lacking. Student t-test revealed that there was significant difference of exchangeable cations between secondary forest and plantain land uses. Similarly, significant difference existed between plantain and oil palm land uses. Further, t-test revealed that there was no significant difference of exchangeable cations between secondary forest and oil palm land uses. Exchangeable cations decreased from surface to subsurface soils in secondary forest

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and oil palm land uses but increased down the soil profile in plantain land use. This research reveals the intense impact of parent materials and land use on exchangeable cations in the study area. Keeping in view the high acidic levels and low status of Ca^{++}, Mg^{++} and Na^{+} in the soils, organic matter and agricultural lime applications are recommended respectively.

Keywords: Erodibility; land use; soil depth; soil fertility index; soil nutrient.

1. INTRODUCTION

Soil is a thin layer of the earth's surface with properties that reflect the impact of man, climate, topography, vegetation, fauna and parent material over time. Geological parent materials are the primary materials from which soils are formed. Hence, [1] reported that parent material is considered as a soil-forming factor affecting soil properties and plant growth. [2] reported that most soil nutrients originate as chemical salts which are released by rock weathering. Hence, the nature of the parent material has a decisive consequence on soil properties. [3] noted that soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution. Properties of the parent material that exert a profound influence on soil development include texture (physical property), mineralogical composition and chemical properties as well as the soil morphology [4]. The chemical nutrients make up the chemical basis of soil fertility. Two main groups exist: Organic sources (N, P, S, SOM etc) and inorganic sources (Ca, Mg, P, Na). However, minerals inherited from the soil parent materials overtime release chemical elements that go through different changes and transformations within the soil. This in turn may influence the properties of the soil. [5] noted that amongst the most conspicuous soil properties that are products of mineral weathering are alkali cations (sodium and potassium etc) and alkaline earth cations (calcium and magnesium). Similarly, [6] affirmed that magnesium contents vary with different parent materials and the climatic locations.

Soil quality status is also influenced by land use systems [7]. Land use is characterized by the arrangements, activities and inputs by people to produce change or maintain a certain land cover type [8]. According to [9], land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. So the success in soil management to maintain soil quality depends on an understanding of how soils respond to land use practices over time. In line with these, [7] report that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes. Sustainability is correlated to soil quality, which is defined as, "the capacity of a specific kind of soil to function, within natural or managed boundaries, to sustain plant and animal productivity, maintain or enhance air and water quality, and support human health and habitation" [10]. Thus, land use is a dominant factor for soil chemical and physical characteristics development. Knowledge of land use impacts on soil quality is indeed indispensable for sustainable agricultural production.

The vulnerability of soil to fertility degradation is determined by its initial chemical status, mineralogy of its parent material, previous vegetation and land use [11]. However, studies on soil quality have been carried out majorly on the impact of land use on soil properties.These includes [12], in evaluating the chemical status of soil in maize fields in Southwestern Nigeria, [13] carried out a study in an Oil Palm plantation, [14] in investigating the effect of land use and soil management practices on soil fertility quality in North China cities' urban fringe, [15] in studying the extent to which land use types influence soil nutrients and productivity in Ogun State amongst others. In addition, the ability of soil to function as a component of an ecosystem may be degraded, aggraded, or sustained in reaction to the effects of parent materials and land use management. Nevertheless, investigations on the impact of parent materials and land uses on soil properties have been scanty. For instance, on the effects of land use and parent materials on trace elements accumulation in topsoil [16], on the effects of parent material and land use on soil phosphorus forms in Southern Belgium [17]. It is based on these premises that this study aims to examine the influence of parent materials and land use on exchangeable cations (Ca++, Mg++, K+, Na+) in a tropical environment, Edo state, Nigeria. This study was carried out with the following objectives; (i) To examine the status of exchangeable cations in the soils (ii) To determine the variation in the exchangeable cations of soils among the different land uses in Okodobo Village. In utilizing soil's ecological functions, this study will help to provide an understanding of the interface between parent materials and land use on exchangeable cations. Knowledge of parent materials and land use impacts on soil quality is also essential for sustainable agricultural production.

This study is conceptually based on the soil quality linkages developed by [18] because of its holistic nature. Soil quality linkages is a conceptual framework that take into consideration the roles played by various individual components in determining the quality of soil (Fig. 1). This is initiated from the specific practices and whole systems having impacts on the soil characteristics which in turn affects the soil processes and finally on the quality of the soil. This research investigation finds this framework useful especially with regards to the impact of specific land use types and parent materials on soil quality which can be assessed via exchangeable cations. This stems from the fact that the soil properties can be altered by both land use types and parent materials.

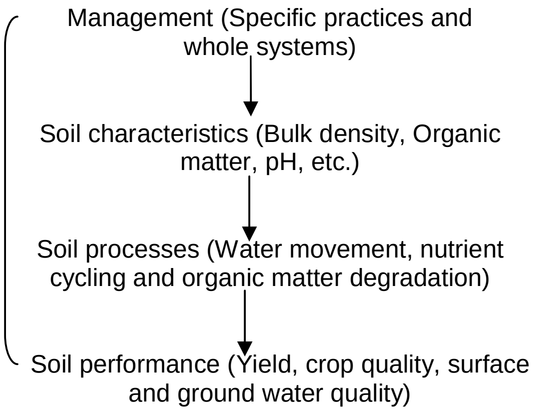

Fig. 1. Soil quality linkages

Source: [18]

2. MATERIALS AND METHODS

The study area is located at Okodobo village (between Lat. 6 32 30N and Long 6 37 30N) as shown in Fig. 2. It has a topography is that characterized by a gentle slope. It experiences the typical rainforest zone climate of southern Nigeria and belongs to Af category of Koppen's climatic classification. Because of the proximal location of the study area to Benin City (24.0 km), it experiences an annual rainfall and temperature similar to the city which [19] puts at above 2000 mm and a mean monthly temperature of 28℃. The soils in the study area are mainly Ferrallitic soils. These are sandy, deeply weathered soils formed from unconsolidated sediments of sandstone and have been intensely leached [20]. The study area was originally of tropical rainforest before man's interference. However, its current vegetation is Secondary forest and the land uses present include arable cropping, shrubs, etc. Human interference has also led to the presence of plantations for rubber *(Havea brasileensis),* oil palm *(Elaesis guneensis)* and plantain *(Musa* spp*).* Extensive exploitation of forest resources and bush burning has combined to reduce some parts of the Secondary forest vegetation. Okodobo village is selected for this study because it is one of the agricultural hubs in Edo State where food and cash crops like yam, cassava, melon, oil palm and rubber are produced both for local consumption and for export.

2.1 Selection of Land Use Types and Transects

The land uses were; Secondary forest (<30 years old) dominated by trees, climbers and woody debris (Plate 1), Oil palm field (<20 years old) with inter-row spaces (Plate 2) and minimal undergrowths due to constant clearing of the plantation and Plantain land use characterized with undergrowths (Plate 3) and harvested annually. Three transects were laid on the three land uses (one for each land use). Each transect was 60 m long and was divided into three parts (20 m apart), which served as the sampling points. The control (secondary forest land use) and treatment plots (plantain and oil palm land uses) served as basis for comparison of exchangeable cations in the different land uses. Both the control and treatment plots are of similar parent materials and climatic characteristics. This makes the comparison of Ca++, Mg++, K+, Na+ on Ferrallitic soils among the different land uses in Okodobo Village possible.

Three-sample collection points were mapped out on each land use along the transect at a distance of 20 m apart. Soil samples were collected by using a soil auger at a depth of 0-15 cm and 15-30 cm from each sampling point and the geographical coordinates of the sampling sites were identified with the use of Global Positioning System (GPS). These depths according to [21] were chosen because 85% of the roots are concentrated in the first 30 cm of the soil column. Similarly, these depths were also adopted to determine the distribution of exchangeable cations between the surface soil (0-15 cm) and subsurface soil (15-30 cm). In each of the land use, six soil samples were collected, thus a total of 18 (eighteen) soil samples were collected for the study. To avoid any mix up, the samples from each sampling point were stored in polythene bags, labeled accordingly and taken to the laboratory where they were air dried at room temperature, crushed and passed through a 2mm sieve for the determination of selected chemical properties.

The physico-chemical parameters analyzed include Ca^2+, K+, Mg^2 +, Na+, pH, CEC, N, P, OM and. Particle size distribution. The pH of the soils was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass-calomel combination electrode [22]. Cation exchange capacity (CEC) and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0. Available soil P was analyzed according to the standard procedure of [23] extraction method. [24] wet digestion method was used to determine soil carbon content and percent soil OM was obtained by multiplying percent soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by [25] by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4). In order to determine the influence of parent materials and land use on the status of the exchangeable cations, soil quality index and threshold values according to [26,27] were used. This was also used in comparing the values of exchangeable cations among the three study sites. However, student t-test was used to determine if there exists any significant difference in exchangeable cations between the control and treatment sites and between the two treatment sites (Plantain and Oil palm land uses).

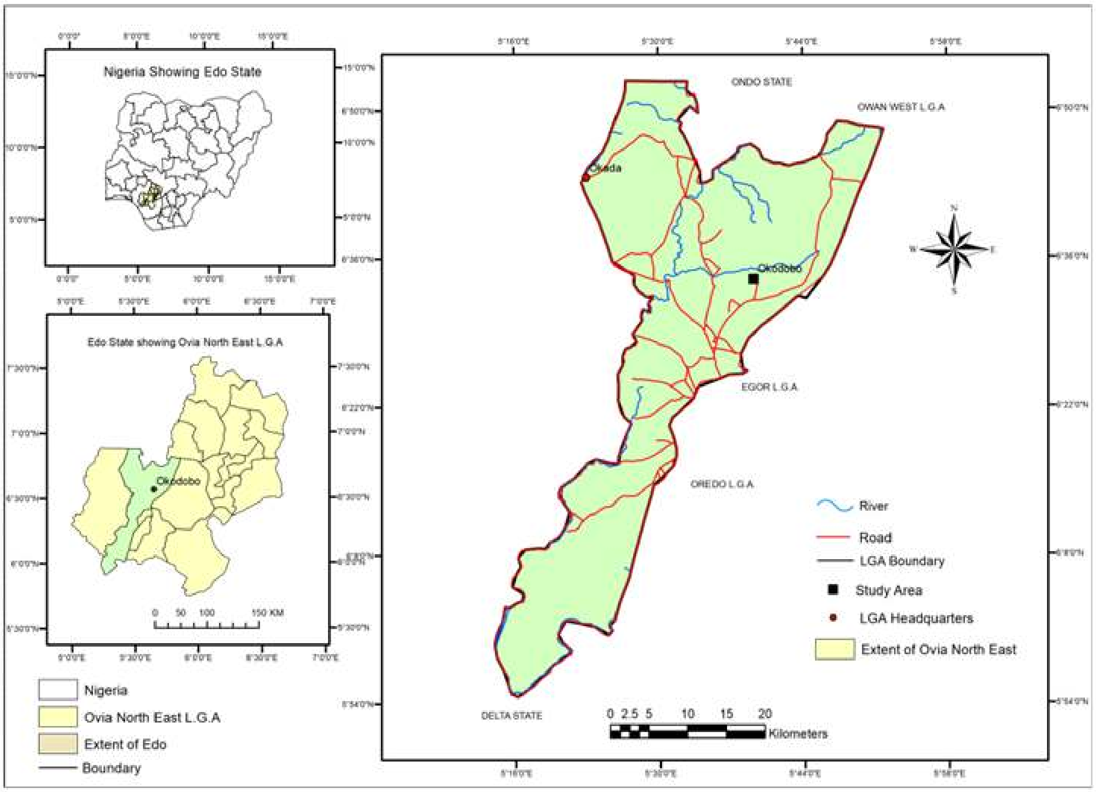

Fig. 2. Study area – Nigeria showing Edo state (Up left), Edo State showing Ovia local Government area (down left) and Ovia local Government area showing Okodobo village (right)
Source: Ministry of lands and surveys, Benin City, Edo State (2013)

Plate 1. Secondary forest land use

Plate 2. Oil palm land use

Plate 3. Plantain land use

3. RESULTS AND DISCUSSION

Table 1 contains the mean values of calcium (Ca) with soil depths (surface and subsurface soils). Secondary forest land use had mean values of 0.29 Cmolkg^{-1} and 0.20 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm) respectively. Under plantain, the mean values was 0.35 Cmolkg^{-1} and 0.36 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm) while for oil palm land use, the mean values was 0.05 Cmolkg^{-1} and 0.02 Cmolkg^{-1} in surface (0-15 cm) and surface soils (15-30 cm) respectively. according to soil quality index by [27], these values at both depths are below 4 Cmolkg^{-1} and therefore qualify for low calcium status of soils in all the land uses. [27] also affirms that the low CEC are responsible for calcium (Ca) deficiency in soils at both surface and subsurface soils. Furthermore, he notes that they were below the range of values of 25 – 40 Cmolkg^{-1} to classify them as high soil fertility. [28] also note that calcium deficiency occurs in acid soils. This is true for this study as pH values observed in both surface and subsurface soils in all the land uses indicate that the soils are generally acidic as their values are less than 5.5 (Table 1). These ranges according to [27] are not within the adequate pH (6.5 – 8.5) for most crop production.

Bolan et al. [29] reported that only highly leached; low-CEC acid soils as observed in the study sites may show Ca deficiency symptoms. Furthermore, [2] reports that on acid parent materials, moderate rainfall may cause leaching of bases such as calcium. This is true for this study as the study area is characterized with excessive rainfall which subsequently increases its erosive power. He also notes that there is less intense mixing of organic and mineral matter owing to lack of earthworms in acidic conditions of the soils. It is on this basis that [30] reports that parent material plays a major role in determining soil Ca concentration. However, on ferruginous soils, [31] observes that the soils were rich in calcium and this may be as a result of calcium rich parent material. Similarly, [32] also observe higher levels of calcium in both secondary forest (3.44 Cmolkg^{-1}) and cultivated (3.24 Cmolkg^{-1}) land uses on ferruginous soils. Similarly, [33] also observed higher levels of calcium (12 cmol kg -1). Their research was carried out on ferrallitic soils in the guinea savannah of Nigeria. Considering the variation of calcium (ca) with soil depth in control and treatment sites, Ca decreased from surface to subsurface soils in both secondary forest and oil palm land uses. However, Ca increased down the profile in plantain land use (Table 1). This may be due to the effects of tree felling in secondary forest and the minimal soil cover in oil palm land use, thus their soil are exposed to the activities of running water on their soil.

In testing for significant difference between Ca content under control and treatment sites, statistical test (t-test) indicated a significant difference (p= 0.04) between the Ca content under secondary forest and plantain land uses (Table 2). This is true for this study as the values of Ca in plantain land use were higher than that of secondary forest. in accounting for the low calcium content in the control site (secondary forest land use (Table 1), [28] affirm that the rate of calcium loss by leaching, tree uptake and harvest exceeds the rate of calcium deposition in most forested soils. however, student t-test indicated that there was no significant difference (p= 0.07) between the Ca content under secondary forest and oil palm land uses (Table 2). This is mainly due to the impact of running water on both land use types. [28] opined that the harvesting of timber as is prevalent in the control site leaves the soil open to erosion and nutrient leaching, leading to rapid losses of calcium from forest ecosystem. Similarly, the activities of running water are also impactful on oil palm soil as its soil is enhanced by the presence of minimal undergrowths on its site. This encourages the loss of Ca in oil palm soil.

Further statistical test (t-test) indicated a significant difference (p =0.02) between the Ca content under plantain and oil palm land uses (Table 2). The higher value of Ca in plantain soils as revealed in Table 5 can be attributed to differences in their ecosystem properties. Plant and residue cover in plantain land use protects the soil from raindrop impact and splash; this tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. However on oil palm soils, low vegetative cover has led to low Ca content on its soil.

The results as indicated in Table 1, reveals the mean values of Potassium (K) with soil depths (surface and subsurface soils). Secondary forest land use had mean values of 6.17 Cmolkg^{-1}and 4.41 Cmolkg^{-1}in surface (0-15 cm) and subsurface soils (15-30 cm) respectively. In Plantain land use, the values were 3.24 Cmolkg^{-1}

and 7.77 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm) while Oil palm land use had mean values of 1.80 Cmolkg^{-1} and 0.85 Cmolkg^{-1} in surface (0-15 cm) and surface soils (15-30 cm) respectively. However, these values according to [27] were above the minimum absolute level of K (0.07 – 0.20 Cmolkg^{-1}) in soils and also above 0.6 Cmolkg^{-1} required for high Potassium levels in soil.

The observed increase in potassium (K) as against other exchangeable cations may be due to the low levels of nitrogen and phosphorus observed in the soils among the different land uses (Table 1). (5) state that high concentration of nitrogen and phosphorus may cause potassium deficiency but when nitrogen and phosphorus levels are comparatively low, then the potassium levels in the soil may be sufficient. It was also observed that Plantain land use had the highest value of K (Table 1). Similarly, [34] observes higher values of potassium in Plantain farms than in soils under Secondary forest (control). He opined that was due to the additions of organic wastes and animal manure (dung and urine) on the plantain farms. However, unlike Ferrallitic soils being the predominant soil in the study area, on Ferruginous soils, [32] observe higher levels of potassium in both Secondary forest (1.28 Cmolkg^{-1}) and cultivated (1.43 Cmolkg^{-1}) land uses. This implies that Ferruginous soils are rich in potassium. Considering the variation of Potassium (K) with soil depth in both control and treatment sites, there was a reduction of K from surface to subsurface soils in both Secondary forest and Oil palm land uses. This is due to the effects of tree felling in the secondary forest land use and minimal soil cover in oil palm land use. These help to expose their soils. However, there was a downward increase in Plantain land use (Table 1).

Table 1. Range and mean values of selected soil properties measured in secondary forest, plantain and oil palm sites on similar lithology

Soil parameters	Depth (cm)	Secondary forest		Plantain		Oil palm	
		range	$\bar{x}$	range	$\bar{x}$	Range	$\bar{x}$
Sand (%)	s	79.80-91.40	85.10	78.50-89.20	84.36	77.90-83.70	81.70
	ss	77.30-84.40	82.46	81.30-87.10	84.03	81.60-86.60	84.76
Silt (%)	s	5.60-15.40	10.40	8.50-17.10	12.86	11.40-16.30	13.03
	ss	11.70-17.60	13.73	9.70-12.90	11.60	9.20-10.80	9.86
Clay (%)	s	3.00-5.70	4.50	1.70-4.30	2.76	4.90-5.80	5.26
	ss	2.60-5.10	3.80	3.20-4.80	4.03	4.20-7.60	5.36
Textural Class	s	loam sandy		loam sandy		loam sandy	
	ss	loam sandy		loam sandy		loam sandy	
Soil reaction (pH)	s	4.00-4.76	4.42	3.78-4.30	4.13	4.78-5.04	4.94
	ss	4.34-4.72	4.53	3.79-4.59	4.15	4.85-4.89	4.87
CEC (Cmolkg^{-1})	s	4.71-22.45	11.3	9.95-20.93	13.62	3.88-5.99	4.67
	ss	3.28-16.74	8.76	5.39-24.48	13.90	3.00-3.70	3.31
Soil organic matter (%)	s	0.69-1.08	2.54	0.62-0.89	2.33	0.57-1.16	2.62
	ss	0.62-0.97	2.27	0.54-0.83	2.10	0.52-1.00	2.31
Phosphorus(mg/kg)	s	0.063-5.70	2.57	2.05-5.28	3.18	0.55-1.09	0.95
	ss	0.35-4.10	1.84	0.84-6.30	3.22	0.28-0.18	0.35
Nitrogen (%)	s	0.05 –0.09	0.07	0.05-0.07	0.06	0.05-0.09	0.07
	ss	0.05- 0.08	0.06	0.04-0.07	0.05	0.04-0.08	0.06
Calcium (Cmolkg^{-1})	s	0.07-0.64	0.29	78.50-89.20	0.35	0.06-0.12	0.08
	ss	0.04-0.46	0.20	81.30-87.10	0.36	0.03-0.05	0.03
Potassium (Cmolkg^{-1})	s	1.51 -13.65	6.17	4.91 -12.63	3.24	1.31 -2.60	1.80
	ss	0.83 -9.81	4.41	2.01 -15.10	7.77	0.68-1.16	0.85
Magnesium (Cmolkg^{-1})	s	0.41-3.69	1.67	1.33-3.42	2.04	0.35-0.70	0.48
	ss	0.23-2.65	1.19	0.54-4.08	2.10	0.18-0.31	0.22
Sodium (Cmolkg^{-1})	s	0.04-0.40	0.18	0.14-0.38	2.04	0.04-0.08	0.48
	ss	0.02-0.29	0.13	0.06-0.44	2.10	0.02-0.03	0.22

Note: x = mean, S=surface soil, SS= subsurface soil

Table 2. Student t-test of the mean calcium content of control (secondary forest land use) and treatment plots (plantain and oil palm land uses)

S/No	Sample pairs	*P*-value
1	secondary forest-plantain	0.04
2	secondary forest-oil palm	0.07
3	plantain-oil palm	0.02

Tested at P=0.05 level of significance

Table 3 reveals student t-test result for K content between control and treatment sites. Statistical test (t-test) indicated a significant difference (p = 0.05) between the K content under Secondary forest and Plantain land uses. This affirms the reason for higher values of K in Plantain land use than in Secondary land use as shown in Table 1. However, student t-test indicated that there was no significant difference (p=0.06) between the K content under Secondary forest and Oil palm land uses. The rate of potassium loss via harvesting of trees is prevalent in forested soils as the soil becomes prone to leaching. Similarly, tree canopy of oil palm is tiny and cannot help to reduce the velocity of rain drop on its soil. These characteristics of both land uses enhance the loss of K. Further statistical test (t-test) indicated a significant difference (p=0.01) between the K content under Plantain and Oil palm land uses. The quality of litter produced by plantain increases as the biomass increases and this enhances the accumulation of K. However, in oil palm land use, the quantity and quality of litter produced is insufficient to help in the accumulation of potassium. This may account for the differences of K contents in Plantain and Oil palm land uses.

Table 3. Student t-test of the mean potassium content of control (secondary forest land use) and treatment plots (plantain and oil palm land uses)

S/No	Sample pairs	*P*-value
1	Secondary forest-plantain	0.05
2	Secondary forest-oil palm	0.06
3	Plantain-oil palm	0.01

Tested at 0.05 level of significance

For Secondary forest land use, the mean values of Magnesium (Mg2+) were 1.67 Cmolkg^{-1} and 1.19 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm). In Plantain land use, the mean values were 2.04 Cmolkg^{-1} and 2.10 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm) while for Oil palm land use, the mean values were 0.48 Cmolkg^{-1} and 0.22 Cmolkg^{-1} in s urface (0-15 cm) and surface e soils (15-30 cm) respectively (Table 1). These values are below 4.0 Cmolkg^{-1} required for high levels of Mg in soils [27]. The acidic nature of the soils in the study sites may have accounted for the observed Mg deficiency as [35] affirm that Mg deficiency is more likely on acidic soils. [28] also report that Mg deficiency is common on very sandy soils with low CEC as observed in the study sites (Table 1). The main source of Mg in most soils is the pool of exchangeable Mg on the clay-humus complex, which is disintegrated due to the acidic nature of the soils. This also accounts for the low clay and soil organic matter contents observed in the soils under the different land uses (Table 1). In addition, results of this study as revealed in (Table 1) indicate that Mg decreased down the profile (from surface and subsurface soils) in both Secondary forest and Oil palm land uses while it increased down the profile in Plantain land use.

Table 4 reveals student t-test result for Mg content between control and treatment sites. A significant difference (p=0.04) between the Mg content under Secondary forest and Plantain land uses was observed. This is true because higher values of Mg was observed in Plantain land use than in Secondary land use (Table 1). This may be due to the greater amount of vegetation biomass producing a larger amount of litter in plantain than in the secondary land use. However the student t-test indicated that there was no significant difference (p=0.07) between the Mg content under Secondary forest and Oil palm land uses. Further statistical test (t-test) indicated a significant difference (p= 0.02) between the Mg content under Plantain and Oil palm land uses. As revealed in Table 1, Mg values were higher in plantain land use than in oil palm. This difference may be due to the dense overhead canopy in Plantain land use and more undergrowth that protects the soil from the direct impact of rain and accelerated soil nutrients decomposition resulting from soil exposure. This enhances the accumulation of Mg on plantain soils. However, low percentage foliage cover under oil palm results in exposing the soil surface to erosion which helps in Mg depletion.

Table 1 indicates the mean values of exchangeable sodium (Na+) observed in both surface and subsurface soils for the three land uses. For Secondary forest land use, the mean values were 0.76 Cmolkg^{-1} and 0.54 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm). Plantain land use had mean values of 0.93 Cmolkg^{-1} and 0.96 Cmolkg^{-1} in surface (0-15 cm) and subsurface soils (15-30 cm) while for Oil palm land use, the mean values were 0.22 Cmolkg^{-1} and 0.10 Cmolkg^{-1} in surface (0-15 cm) and surface soils (15-30 cm) respectively.

Table 4. Student t-test of the mean magnesium content of control (secondary forest land use) and treatment plots (plantain and oil palm land uses)

S/No	Sample pairs	*P*-value
1	Secondary forest-plantain	0.04
2	Secondary forest-oil palm	0.07
3	Plantain-oil palm	0.02

Tested at 0.05 level of significance

The result indicated that exchangeable sodium was lowest in the Oil palm land use than in soils under Plantain and Secondary forest land uses (Table 1). This reflects the activities of increased leaching of cations occurring in soils under Oil palm land use due to the presence of its minimal soil under growths. However, the highest average amount of exchangeable Na was measured in soils formed on Plantain land use. This can be attributed to the restricted leaching of cations occurring in the soils due to the presence of soil undergrowths. Similarly, the foliage of Plantain is larger than that of other studied land uses and this helps to reduce the intensity of raindrops on its soil.

Sodium is classified based on exchangeable sodium percentage (ESP) which is the percent of sodium in CEC. According to the 15% threshold values of exchangeable sodium percentage (ESP) as indicated by [26], the results of this study reveal that in all the study sites at both the surface and subsurface soils, the amount of exchangeable Na was less than 15% of the CEC (Table 1). Similarly, this study aligns with that of (1); where they observed that in all cases, the amount of exchangeable Na was less than 15% of the CEC. Furthermore, in analyzing the variation of sodium (Na) with soil depth in the different land uses, Na increased down the profile in Plantain land use while it decreased from surface and subsurface soils in both Secondary forest and Oil palm land uses (Table 1).

Table 5 reveals student t-test result for Na content between control and treatment sites. It indicated a significant difference (p=0.04) between the Mg content under Secondary forest and Plantain land uses. This is true for this study as higher values of Na was observed in Plantain land use than in Secondary land use as shown in Table 1. However no significant difference (p= 0.06) between the Na content under Secondary forest and Oil palm land uses was noticed. It is probable that the rates of nutrient uptake by oil palm greatly exceed the rates of nutrient return to the soil through litter fall and mineralization during the rapid phase of oil palm growth. Similarly, in forest ecosystem, most soil nutrients are more in the biomass than in soils being that their biomass is larger than that of other vegetal ecosystems and their soils are prone to leaching.

Further statistical test (t-test) indicated a significant difference (p= 0.01) between the Na content under Plantain and Oil palm land uses (Table 5). As revealed in Table 1, Na values were higher in plantain land use than in oil palm. This variation may be due to the fact that litter in oil palm land use is largely in the form of fronds and they decompose more slowly than the leaf litter in plantain land use. The resultant effect of this is that when accelerated decay sets in, palm fronds are not readily humified to compensate the rate of sodium loss from the soil.

Table 5. Student t-test of the mean sodium content of control (secondary forest land use) and treatment plots (plantain and oil palm land uses)

S/No	Sample pairs	*P*-value
1	Secondary forest-plantain	0.04
2	Secondary forest-oil palm	0.06
3	Plantain-oil palm	0.01

Tested at 0.05 level of significance

4. CONCLUSION AND RECOMMENDATIONS

It is clear from the study that K was moderate in soils under the different land uses while Ca, Mg, and Na were deficient. This research revealed that the high acidic content of the soils and the erodibility of mineral deficient parent material, sandstone caused the disintegration of clay particles and the solubility of organic matter. Hence, the soils lacked the ability to bind soil exchangeable cations. Considering the variation of exchangeable cations with soil depth, this paper showed that exchangeable cations decreased with soil depth in Secondary forest and Oil palm land uses. However in Plantain land use, exchangeable cations increased with depth. These soil nutrients might be dissolved easily into the deep layer of soil because of heavy rainfall. Hence the subsoil is playing an important role as a nutrient storage zone. The study showed that there exist significant differences of exchangeable cations between secondary forest and plantain land use types as well as between plantain and oil palm land use types. This is largely due to differences in their ecosystem properties. However, no significant difference of exchangeable cations was observed between secondary forest and oil palm land uses. This is essentially as a result of the impact of anthropogenic activities (tree felling) in the secondary forest as well as the occurrence of minimal soil cover in oil palm land use. Hence, their soils are exposed and prone to the effects of running water. The observed pattern in the sites indicates that soil under plantain appears to be of higher exchangeable cations than soils under secondary forest and oil palm land uses. However, soil exchangeable cations were significantly lower in soils under oil palm than in soils under forest and plantain land uses. This can be credited to the fact that the sites farmed under the oil palm system do not replicate the conditions in the forest and plantain ecosystems. It is recommended that organic matter and agricultural lime applications are undertaken so as to enhance the availability of Ca^{++}, Mg^{++} and Na^{+} and to reduce the high acidic content in the soils.

ETHICAL APPROVAL

Authors were very mindful of ethical regulations and hereby submit that all relevant authorities consulted were cited unless where unintentional omitted (if any). The study (both field and laboratory work) were done under strict ethical code of conduct and was privately financed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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